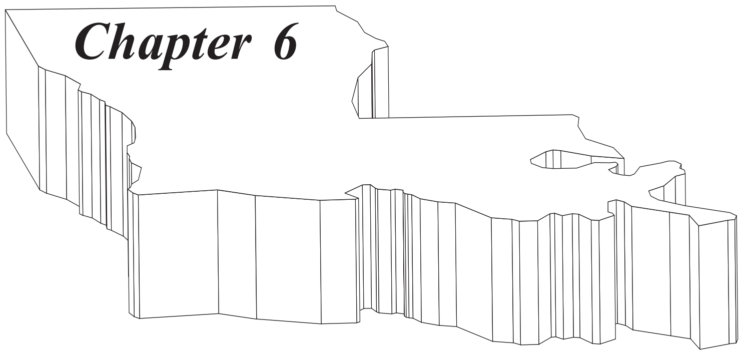
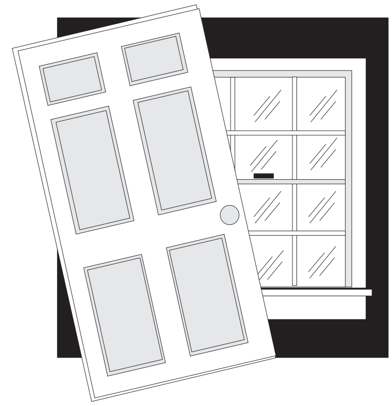
Chapter 6





Windows and Doors

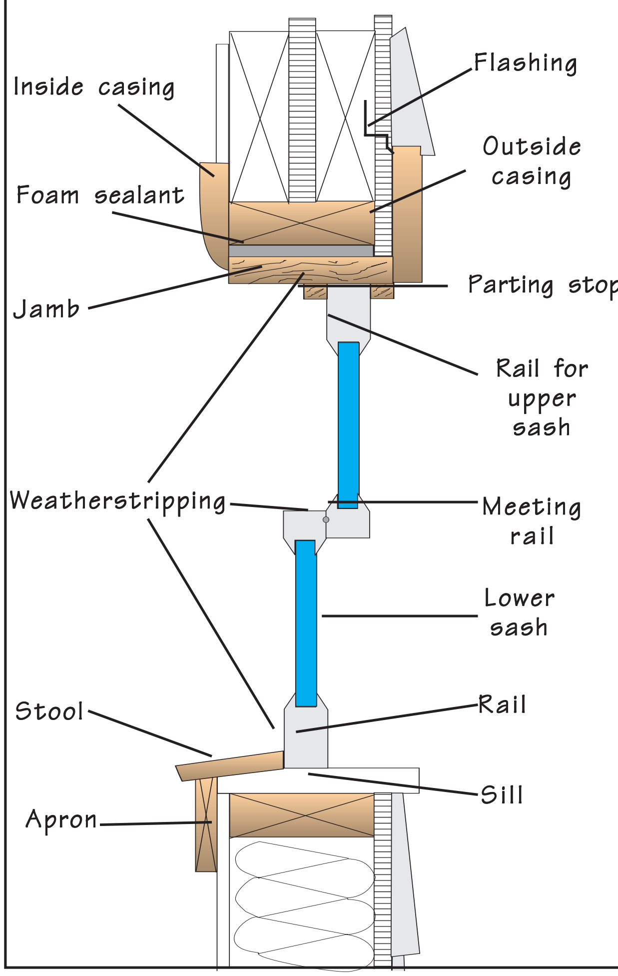
Windows connect the interior of a house to the outdoors, provide ventilation and daylight, and are one of the key aesthetic elements. In passive solar homes, windows can provide a significant amount of heat for a house in the winter.

Windows and doors are often the architectural focal point of residential designs, yet they provide the lowest insulating value in the building envelope. Although recent developments in energy efficient products have markedly improved the efficiency of windows, they still pose a major energy liability.

The type, size, and location of windows greatly affect heating and cooling costs. Select good quality windows, but shop wisely for the best combination of price and performance. Many house building budgets have been blown by spending thousands of additional dollars on premium windows with marginal energy savings. In general, if the windows are double-glazed, well-built, and have good weatherstripping, they will serve you well. Check on added features, such as low-emissivity coatings, inert gas fill between glazing layers, and tinted or reflective units —they may provide additional energy savings at relatively low extra cost.

Well designed homes carefully consider window location and size. In summer, unshaded windows can double the costs of keeping a house cool. Year round, poorly designed windows can cause glare, fading of fabrics, and reduced comfort. Chapter 11 on Natural Cooling describes how to shade windows to save even more energy.

Figure 6-1
Window Anatomy



Windows

To understand new window technologies, it is helpful to know how they lose and gain heat:

- ❒ Conduction through the glass, edge, and frame
- ❒ Convection across the air space in double- and triple-glazed units
- ❒ Air leakage around the sashes and the frame
- ❒ Radiant energy from the sun transmitted through the glazing
- ❒ Radiant energy from inside emitted to the night winter sky

Goals of Efficient Windows

- ❒ Good insulating values - low U-values (High R-values) — a minimum of double-glazed glass (U-0.65) with thermal breaks in metal-framed units
- ❒ Low air leakage rates:
  - ❍ less than 0.25 cfm per linear foot of sash opening for double-hung windows
  - ❍ less than 0.10 cfm per linear foot for casement, awning, and fixed windows
- ❒ Moderate to high transmission of visible light (Visible Light Transmission = 50% to 80%)
- ❒ Low transmission rates of ultraviolet and infrared light (Solar Heat Gain Coefficient — SHGC — 0.4 or below)

Figure 6-2
Winter Heat Loss in a Typical Clear Double-glazed Window

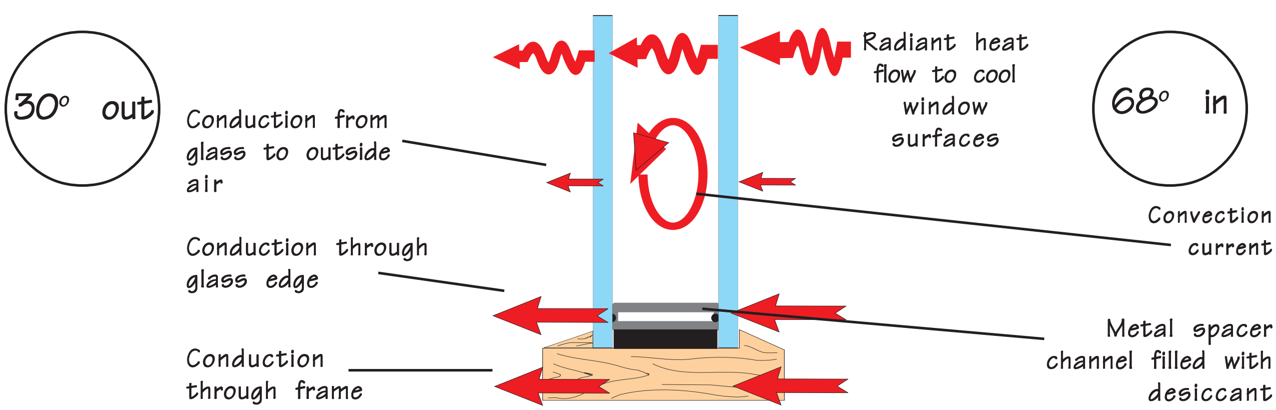
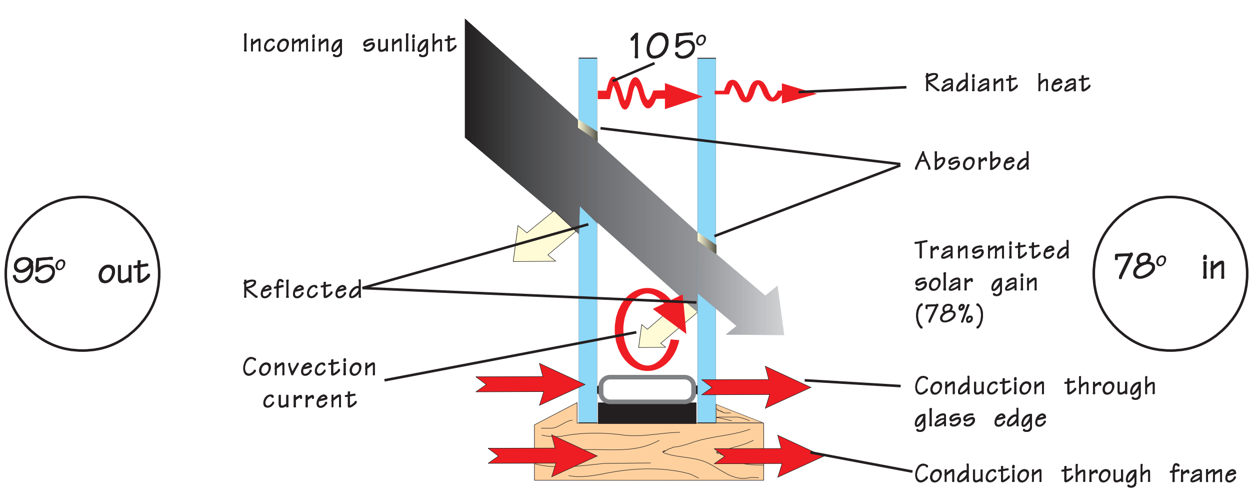


Figure 6-3
Summer Heat Gain in a Typical Double-glazed Window



Measurements of Window Performance

When shopping for windows, it's useful to know some of the basic window terminology:

NFRC -- the National Fenestration Rating Council, a national nonprofit organization publishes a directory of windows that have been tested according to their criteria. The NFRC rating system is described later in the chapter. Builders should use windows with an NFRC label, as their listed insulating values and air tightness have been verified by independent laboratories.

R-value and U-value -- ratings given for the insulating values of windows. R-values refer to the resistance to heat flow; therefore, the higher the R-value, the better the insulation. U-values measure the ability of the window to conduct heat and are the inverse of the R-value -- the lower the U-value the better. Standard wood double-glazed windows have R-values of about 2, thus having U-values of 1/2. A typical new window having a low-emissivity coating and an inert gas in the air space might have an R-value of 3.3, or a U-value of about 0.30.

Solar Heat Gain Coefficient -- the fraction of solar heat that actually penetrates a window and enters the living area of a home. A window with a SHGC of 80% lets about 4 times as much solar radiation into a home as a window with a SHGC of 20%. To reduce summer cooling bills, windows with lower SHGC will save money. However, in passive solar homes for heating, these same windows may not provide the savings of clearer window units. Tinted and reflective windows, or units with solar films, have low SHGC ratings.

Shading Coefficient -- an older method of measuring solar heat transfer. This method of indicating the relative solar transmission through windows assigns single-glazed clear windows a Shading Coefficient of 1.0. Double-glazed windows have Shading Coefficients of 0.87. If you know the Shading Coefficient of a window, you can find the SHGC by multiplying the Shading Coefficient by 0.88.

Visible Light Transmittance -- a measure of the percentage of available visible light that penetrates a window.

Infiltration -- the rated air leakage of the window is usually measured in cubic feet per minute of leakage per linear foot of crack around the window unit. Double-hung units are typically the leakiest, while fixed units are the tightest.

Window Types -- Figure 6-4 depicts some of the different window types available on the market today. All types are generally available with wood, pre-primed wood, aluminum clad, and vinyl frames:

Double-hung and single-hung windows -- most traditional, leakiest, only open halfway when ventilating, greatest surface to paint, less expensive.

Fixed windows -- very low air leakage, provide no ventilation, have the least interrupted view, less expensive.

Casement, Awning, and Hopper Windows -- low air leakage, open fully for ventilation but sash may receive direct rainfall, more expensive.

Figure 6-4
Types of Windows

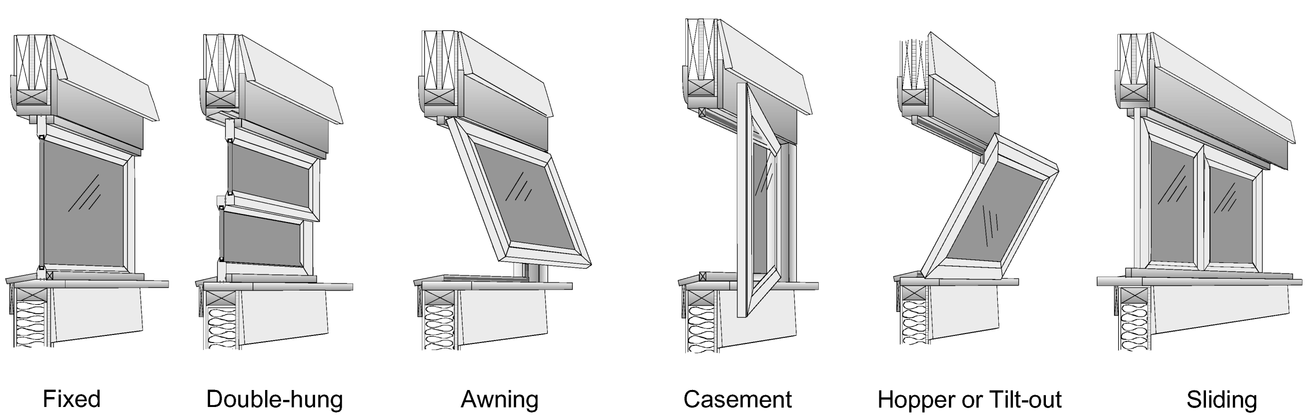


Table 6-1
Cost Comparison of Window Alternatives
(in $/square foot of rough opening)

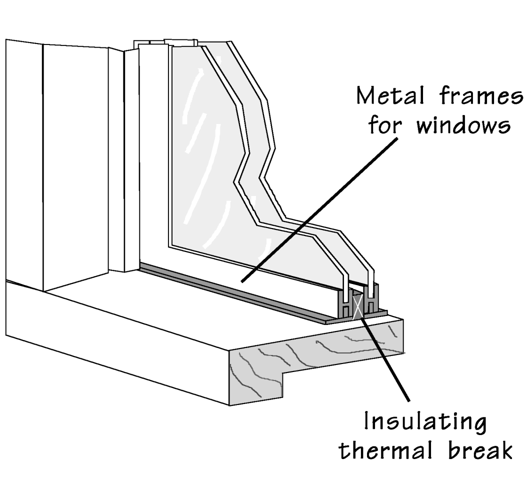
Type of Window	Builder's Quality	Premium Quality
Single-glazed:		
Double-hung wood	5	11 - 18
Double-glazed:		
Double-hung—wood	8	11 - 18
Double-hung—vinyl or aluminum clad	10	12 - 25
Casement or awning—wood	14 - 18	20 - 27
Casement or awning—aluminum or vinyl clad	19 - 23	25 - 31
Sliding glass door—metal	5 - 8	7 - 10
Sliding glass door—wood	9 - 14	10 - 15
Fixed/hinged operable door combination	n/a	11 - 18

*Windows generally cost about $50 in labor to install. Sealed, double-glazed glass units cost about $2.50 per square foot not including labor and trim, which may run about $7 per square foot of rough opening.

Few windows can meet all of these goals, but in the past several years, the window industry has unveiled an exciting array of higher efficiency products. The most notable developments include:

- Low-emissivity coatings, which hinder radiant heat flow
- Tighter weatherstripping systems to lower air leakage rates
- Inert gas fills, such as argon and krypton, that help deaden the air space between layers of glazing and thus increase the insulating values of the windows
- Thermal breaks to reduce heat losses through highly conductive glazing systems and metal frames
- Windows with low transmission rates of radiant and ultraviolet radiation

Figure 6-5
Metal Window Frame With Thermal Break



Thermal Breaks and Window Spacers

Thermal breaks in metal window frames are of particular importance. Metal is a very poor insulator—in fact, it is a conductor of heat. A thermal break separates inside and outside pieces of the window frame with an insulating material, thus improving insulating values. Always specify windows with thermal breaks, listed as "T.I.M." (thermally insulated metal) when purchasing metal windows.

When shopping for windows, find out the total U-value, not just that for the glass. Also, ask how the U-values are determined and whether any standard test procedures were used to derive it. It makes no sense to pay top dollar for a window that looks great on paper, but performs poorly in the real world.

Table 6-2
Sample Window Performance Characteristics

Type	U-value	Solar Heat Gain Coefficient	Visible Light Transmission	Infiltration (cfm/lin ft of crack)
DH, 1G, wood *	1.10	0.79	0.90	0.20 - 0.35
DH, 1G, metal	1.30	0.79	0.90	0.50 - 0.98
DH, 2G, wood	0.49	0.58	0.81	0.15 - 0.30
DH, 2G, wood , bronze tint	0.49	0.55	0.61	0.15 - 0.30
DH, 2G, metal (no thermal break)	0.75	0.58	0.81	0.25 - 0.50
DH, 2G, metal (with thermal break)	0.64	0.58	0.81	0.25 - 0.50
CS, 2G, wood	0.45	0.58	0.81	0.07 - 0.15
CS, 2G, vinyl	0.48	0.58	0.81	0.07 - 0.15
CS, 2G, low-e, wood	0.38	0.50	0.74	0.07 - 0.15
CS, 2G, low-e, inert gas fill, wood	0.30	0.50	0.74	0.07 - 0.15
CS, 2G, low-e, inert gas fill, wood, low solar gain coating	0.29	0.31	0.72	0.07 - 0.15
DH, 3G, low-e, inert gas fill, wood	0.24	0.37	0.68	0.15 - 0.30
DH, 4G, low-e, inert gas fill, wood	0.17	0.30	0.62	0.15 - 0.30

* Ratings shown are for the entire window unit, not just the center of glass. Double and triple glass systems have 0.5" air spaces between the layers of glass. DH = Double hung, CS = Casement (awning and hopper would have similar air leakage values, fixed would have lower air leakage). 1G=single glazed, 2G=double-glazed, etc.

LOW - EMISSIVITY COATINGS

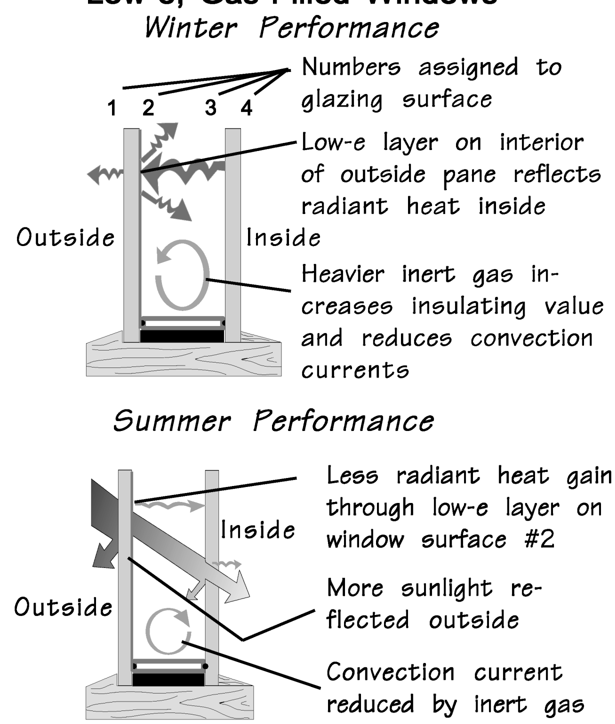
Low-e coatings are designed to hinder radiant heat flow through multi-glazed windows. Some surfaces, such as flat black metal used on wood stoves, have high emissivities and radiate heat readily. Other surfaces, such as shiny aluminum, have low emissivities and radiate little heat, even when at elevated temperatures.

Most low-e coatings are composed of a layer of silver applied between two protective layers. The coatings have swept through the window industry. Several window companies rarely sell products without low-e layers applied.

There are many benefits of low-e windows in addition to reducing summer heat gain and winter heat loss. They screen ultraviolet radiation, which can reduce fabric fading. In winter, the inside surface of the glass is warmer, which makes us feel warmer and helps prevent condensation and frosting.

Figure 6-6 shows that window surfaces are numbered -- 1 to 4 from outside to inside for double-paned units. In Louisiana and other areas where cooling is more important than heating, the low-e layer should be on the #2 surface.

Figure 6-6
Low-e, Gas-Filled Windows



Caution about Window Insulating Values

Window insulating values are typically reported in U-values — the inverse of R-values. Double-glazed products have R-values as high as 2.0, or U-values of about 0.50 (1/R = 1/2 = 0.50). Single-glazed windows generally have R-values of 1.0 and thus have U-values of 1.0.

The National Fenestration Rating Council (NFRC) offers a voluntary testing program for window and door products. The NFRC reports an average whole window U-value and R-value. If windows used in your home are listed by the NFRC, they will include a label showing test data for your windows.

Often, window R-values are reported as the insulating value through the glass surface alone. However, windows are made of more than just glass. They have a frame or sash; spacer strips, typically made of aluminum, that hold the sections of glass in a double-glazed window apart; and a jamb. The claimed R-value should reflect the overall insulating value of all of the components. New procedures are encouraging all manufacturers to report window R-values consistently and accurately.

For example, there are two companies which produce extremely efficient windows. Both have two outer glass panes and two inner layers of low-e coated film. In one case, all air spaces are filled with argon, providing an R-value of 7.8 for the glass. However, losses through the edges and frames lower the overall window R-value to 4.0. Another window is filled with air rather than argon yielding an R-value of 6.6 for the glass. Due to its unique edge system, which has thermal breaks made of nylon spacers with insulation in between, the overall window R-value is about 6.3 — 50% greater than that for the window with higher glass R-value. Future development in windows will concentrate on both glass technology and the balance of the window — edges, seals, and frames.

Figure 6-7
NFRC Label

nfrc CM CERTIFIED

National Fenestration Rating Council Incorporated

Sample Window Company

Manufacturer stipulates that these ratings were determined in accordance with applicable NFRC procedures.

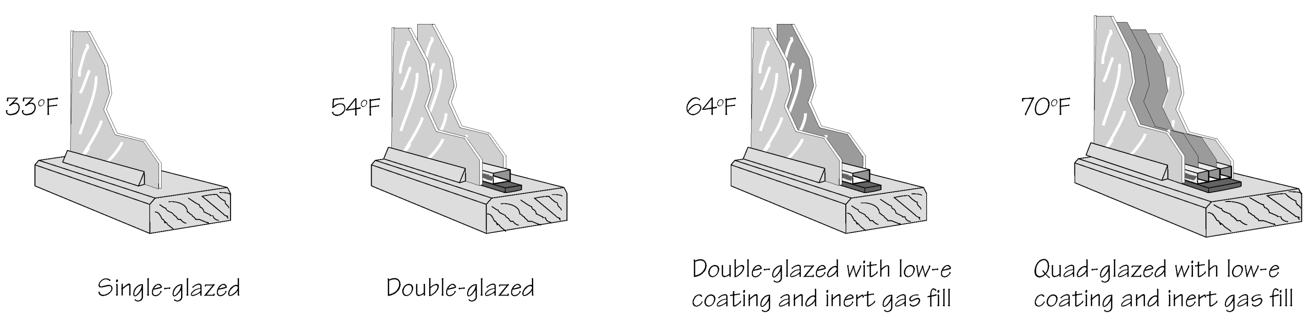
Energy Rating Factors	Ratings: Residential	Ratings: Nonresidential	Product Description
U-Factor Determined in Accordance with NFRC 100.	0.4	0.39	Model 1000 Casement
Solar Heat Gain Coefficient Determined in Accordance with NFRC 200.	0.4	0.4	Low-e = 0.2 0.5" gap
Visible Light Transmittance Determined in Accordance with NFRC 300 & 301	0.48	0.48	Argon filled
Air Leakage Determined in Accordance with NFRC 400.	0.1	0.1	

NFRC ratings are determined for a fixed set of environmental conditions and specific product sizes and may not be appropriate for directly determining seasonal energy performance. For additional information, contact: __________

NFRC labels also show the following key window performance features:

- Air leakage rates
- Solar heat gain coefficient — the fraction of sunlight transmitted through the window
- Visible light transmittance — the fraction of visible light that is transmitted

Figure 6-8
Inside Window Temperatures in Cold Weather (when 75°F inside and 20°F outside)



PROPER WINDOW INSTALLATION

Step 1: Make sure window fits in rough opening and that the sill is level.

Step 2: Install window level and plumb according to the manufacturer's instructions.

Step 3: Use a dry, pliable foam gasket or non-expanding foam sealant to seal between the jamb and the rough opening, or stuff the gap with backer rod or insulation and cover the insulation with caulk (remember — most insulation doesn't stop air leaks — it just serves as a filter).

Step 4: If using an interior air barrier (such as drywall) or exterior air barrier (such as housewrap), seal the barrier to the window jamb with long-life caulk or other appropriate, durable sealant.

Future Window Options

Electronic windows

A new genre of windows are composed of special materials that can darken the glazing by running electricity through the unit. Some manufacturers already have prototypes of these high technology windows in operation. At night and on sunny days, an electric switch can be turned on to render the windows virtually opaque.

Solid windows

Another new window technology uses gel-type material up to one inch thick between layers of glazing. The window offers increased insulating value, but at present is not completely transparent and is not economical in Louisiana.

Table 6-3
Economics of Energy Conserving Windows and Doors*
(compared to single-glazed windows)

Type of Treatment	Energy Savings ($/yr)	Extra Costs ($)**	Rate of Return	Extra Annual Mortgage ($/yr)
Windows				
1. Double-glazed (R-1.8)	116	660	19%	53
2. Double-glazed with low-e coating (R-2.4)	157	1,110	16%	89
3. Double-glazed with low-e coating and inert gas fill (R-2.7)	186	1,260	17%	101
4. Triple-glazed, low-e coating, inert gas fill (R-3.2)	235	1,710	15%	138
5. Quad-glazed, low-e coating, inert gas fill (R-5)	245	2,900	9%	232
Doors (compared to solid wood doors)				
1. Foam-insulated doors (R-5)	5	20	26%	2
2. Storm doors over wood doors (R-3.2)	3	90	n/a	9

* Savings and costs are for a home with 300 square feet of windows and 2 exterior doors located in Baton Rouge, LA.

**Extra annual mortgage for 30-year loan @ 7% annually would be 0.08 times the initial cost. For example, double glazed windows cost an extra $660, which would add about $53 (0.08 x $660) to the annual mortgage.

Doors

Exterior wood doors have low insulating values, typically R-2.2. Storm doors increase the R-value only to about R-3.0 and are not good energy investments. The best energy-conserving alternative is a metal or fiberglass insulated door. Metal doors have a foam insulation core which can increase the insulating value to R-5 or greater. They usually cost no more than conventional exterior doors and come in decorative styles, complete with raised panels and insulated window panes.

Insulated metal or fiberglass doors usually have excellent weatherstripping and long lifetimes. They will not warp and offer increased security; however, they are difficult to trim, so careful installation is required. Table 6-3, shown earlier, examines the costs and savings of energy conserving doors. As with windows, it is important to seal the rough openings. Thresholds should seal tightly against the bottom of the door and must be sealed underneath. After the door is installed, check it carefully when closed to see if there are any air leaks.

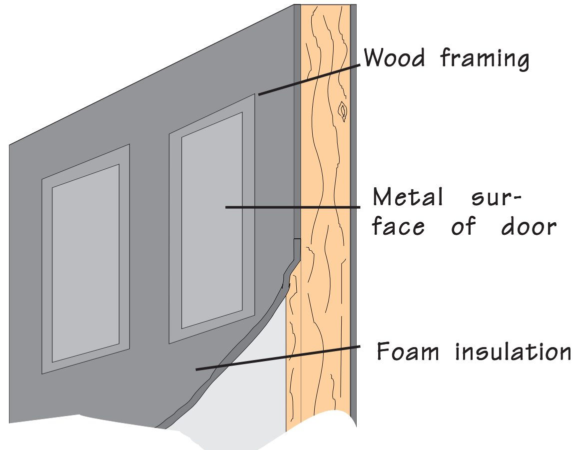
Accessible Design

Almost one out of ten people will suffer from physical disabilities during their lifetime. Designing homes to provide accessibility for the physically impaired adds little to the cost of a home. One important feature is to design both exterior and interior door openings and hallways 3'-0" wide to allow passage of a wheelchair or walker. Ensuring that baths and kitchens have adequate room for wheelchairs is another feature that adds little to construction costs but is expensive to retrofit.

Overall Window and Door Recommendations

- Use double-glazed windows with low-e coatings and inert gas fill. The low-e coating should be applied to the outer pane of the glass to help its performance in summer.
- South-facing windows should be clear and shaded with about a 2-foot horizontal overhang for single-story windows.

Figure 6-9
Insulated Metal Door



- East and west facing windows should have low Solar Heat Gain Coefficients through the use of tinting, reflective or selective coatings, or window films. West window areas, in particular, should be limited to avoid afternoon solar gain.
- North windows, while avoided in northern climates, are excellent for indirect lighting and ventilation.
- Insulated doors should be used, with the possible exception of a front accent door. Designers should consider attractive fiberglass entry doors that are now available as well.